

**Radiation Thermometry at NIST: An Update of
Services and Research Activities**

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Abstract

An overview of activities at NIST in radiation thermometry and related temperature scale research is presented. An expansion of calibration services for pyrometers will be described as well as efforts to develop calibration services for blackbody simulators. Research relevant to the realization of the new international temperature scale (ITS 90) will be discussed.

Introduction

At the last NASA noncontact temperature measurement workshop, held on 30 April - 1 May 1987, a summary of relevant activities conducted by the Radiometric Physics Division of the National Institute of Standards and Technology (NIST) was presented. Since that time, the scope of our activities has continued to expand to meet the evolving measurement needs of the user community. In addition to developing new calibration services, we are contributing to the imminent redefinition of the international temperature scale with fundamental measurements of the freezing point of gold.

Pyrometer Calibrations

The primary activities at NIST relevant to radiation thermometry have always revolved around our mandate to maintain and disseminate the national temperature scale above the temperature of freezing gold (1064.43°C). To this end, the radiance temperature scale is maintained and disseminated¹ on tungsten strip lamps calibrated in the range 800°C to 2300°C . Additionally optical pyrometers, both visual and automatic, are calibrated in their design range. These calibrations are performed in a facility which is shown schematically in figure 1. Both scale realization and lamp and pyrometer calibrations have traditionally been done near 650 nm. In our laboratory, the actual wavelength used was for many years 654.6 nm and is currently 655.3 nm.

Over the past few years, the silicon photodetector based pyrometer operating in the 0.8 to 1.2 micrometer range has become increasingly prevalent. While we have calibrated a limited number of these instruments on a special test basis, it is clear that there is sufficient demand to warrant a formal calibration service. To meet this need, the facility in figure 1 is being extensively modified. A large area blackbody has been added to accommodate the larger spot size of these instruments and the calibration pyrometer is now undergoing a redesign. These modifications are well underway and we are working to establish a calibration service.

Calibration of Ambient Temperature Blackbodies

Blackbodies operating in the 5°C - 100°C range are often used to calibrate thermal imaging systems and imaging radiometers. These are usually not cavity radiators but are most commonly in the form of flat plates having active areas of several square centimeters. In particular, Forward Looking InfraRed (FLIR) systems, used by all branches of the armed forces as well as a variety of infrared scanners, are maintained with a calibration chain based on such blackbodies. To support such devices we have for a number of years maintained a calibration facility. To meet the need for increased accuracy these facilities have been

undergoing a systematic upgrade and expansion.

The heart of the new facility is a water-bath blackbody² (WB BB) designed and built at NIST. The design goals include a large-area (ten centimeter diameter aperture) blackbody with an effective emissivity of .99 or better. It is required to operate from 5°C - 60°C with a setpoint stability of $\pm .01^\circ\text{C}$ and have a central area of the ten centimeter aperture that is uniform to $\pm .01^\circ\text{C}$. Two such systems have been incorporated into the calibration facility, shown schematically in figure 2, and verification of the design parameters is well underway.

Development of the water-bath blackbodies is continuing and a second generation design will be completed by the end of this year. Ultimately, we hope to demonstrate stability and uniformity better than $.005^\circ\text{C}$.

Calibration of Medium Temperature Blackbodies

In the past year, it was determined that sufficient need exists for the calibration of blackbodies operating in the 350°C - 1000°C range to warrant the design and construction of a dedicated facility. Shown schematically in figure 3, the facility will be built around two pressure controlled heat pipe³ furnaces modified as blackbody simulators. One furnace will cover the temperature range of 350°C - 700°C by using cesium as a working fluid while the second furnace will be sodium charged and will operate from 550°C - 1050°C. The cavities themselves will be cylindro-cones 60 centimeters deep and 5 centimeters in diameter. The use of pressure controlled heat pipes will result in stability and uniformity better than $.01^\circ\text{C}$.

The choice of radiometer for this facility has not been made. Occasional calibrations performed in the past used a scanning monochromator and were primarily in the 3 - 5 micrometer band with a limited amount of work in the 8 - 14 micrometer band. We plan to expand our working range and will investigate the feasibility of covering the entire 2 - 20 micrometer range. We are actively pursuing the possibility of using a Fourier transform radiometer to achieve this.

Temperature Scale Research

The International Practical Temperature Scale is defined in terms of a number of primary fixed points and specifications for interpolation between them. The upper fixed point on the scale, as defined in 1968 (ITS-68), is the temperature of freezing gold (gold point). Above this point, temperature is defined radiometrically by Planck's law. In ITS-68 the gold point was specified as 1337.58 K (1064.43°C). In the years since the scale was issued a consensus has emerged that the value is about 0.3 K too high.

In our laboratory, a unique experiment is underway⁴ to perform an absolute radiometric measurement of the gold point. Shown schematically in figure 4, this experiment measures the freezing temperature of gold by directly comparing the spectral radiance of a gold point blackbody with that of a laser irradiated integrating sphere that has been calibrated by both silicon detector standards (Si) and an electrically calibrated radiometer (ECR). Preliminary results give a temperature of 1337.32 \pm 0.36 K (3σ).

On January 1, 1990 it is anticipated that a new international temperature scale will be implemented (ITS-90). It will involve reassignments of a wide range of fixed points. (Table 1 shows the effect on radiance temperature if the downward adjustment in the gold point is 0.3 K.) In addition to these reassignments, the upper part of the new scale is expected to be defined radiometrically from the freezing point of silver, currently given in IPTS-68 as 1235.08 K. This value will be reassigned in ITS-90 and we will explore the possibility of employing the same technique used to measure the gold point to perform a silver-point measurement.

Table 1. Projected change in radiance temperature resulting from -0.3 K reassignment of the gold-point temperature from 1337.58 K to 1337.28 K.

Radiance Temperature	Quoted Uncertainty (NIST 3σ)	Change of Value
800°C	$\pm 0.5^\circ\text{C}$	-0.2°C
1100	0.6	-0.3
1400	0.8	-0.5
1800	1.3	-0.7
2300	2.0	-1.1

Summary

A summary of recent and ongoing activities relevant to radiation thermometry has been presented. Because of the wide scope of the work, only a very brief overview has been possible. Anyone desiring further information concerning these or other activities of the Radiometric Physics Division or who wishes to suggest new directions we might pursue is encouraged to contact us directly.

References

1. W. Waters, J. Walker, and A. Hattenburg, Radiance Temperature Calibrations, NBS Special Publication 250-7, October 1987
2. J. Geist and J. Fowler, A Water Bath Blackbody for the 5 to 60°C Temperature Range: Performance Goal, Design Concept, and Test Results; NBS Technical Note 1228, October 1986
3. C. Busse and C. Bassani; A New Generation of Precision Furnaces, in Temperature: Its Measurement and Control in Science and Industry (American Institute of Physics, 1982) Vol 5, p 1265
4. K.D. Mielenz, R.D. Saunders, and J.B. Shumaker, Spectroradiometric Determination of the Freezing Temperature of Gold (submitted for publication)

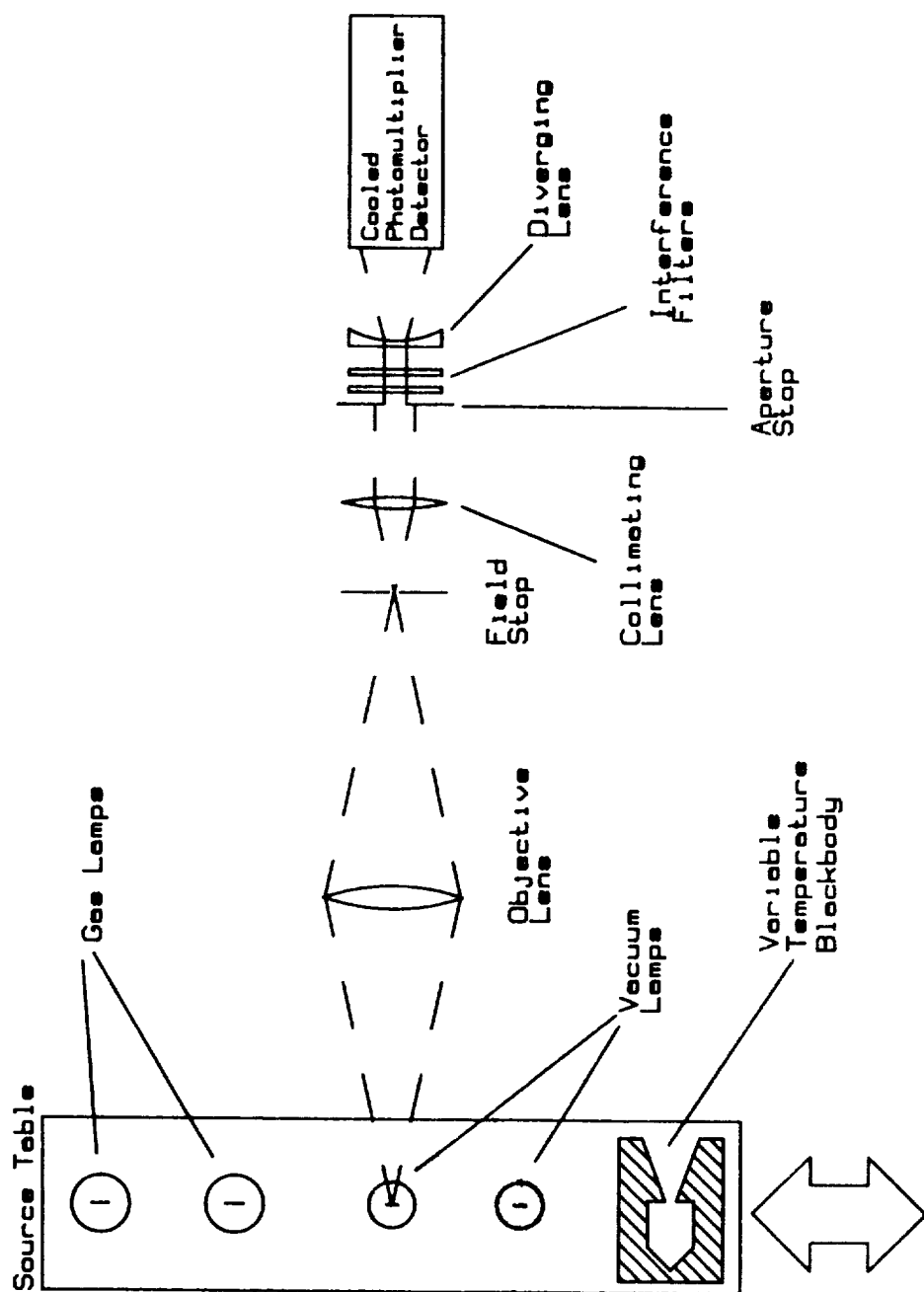


Figure 1. Schematic of the Calibration Facility based on the NIST Photoelectric Pyrometer

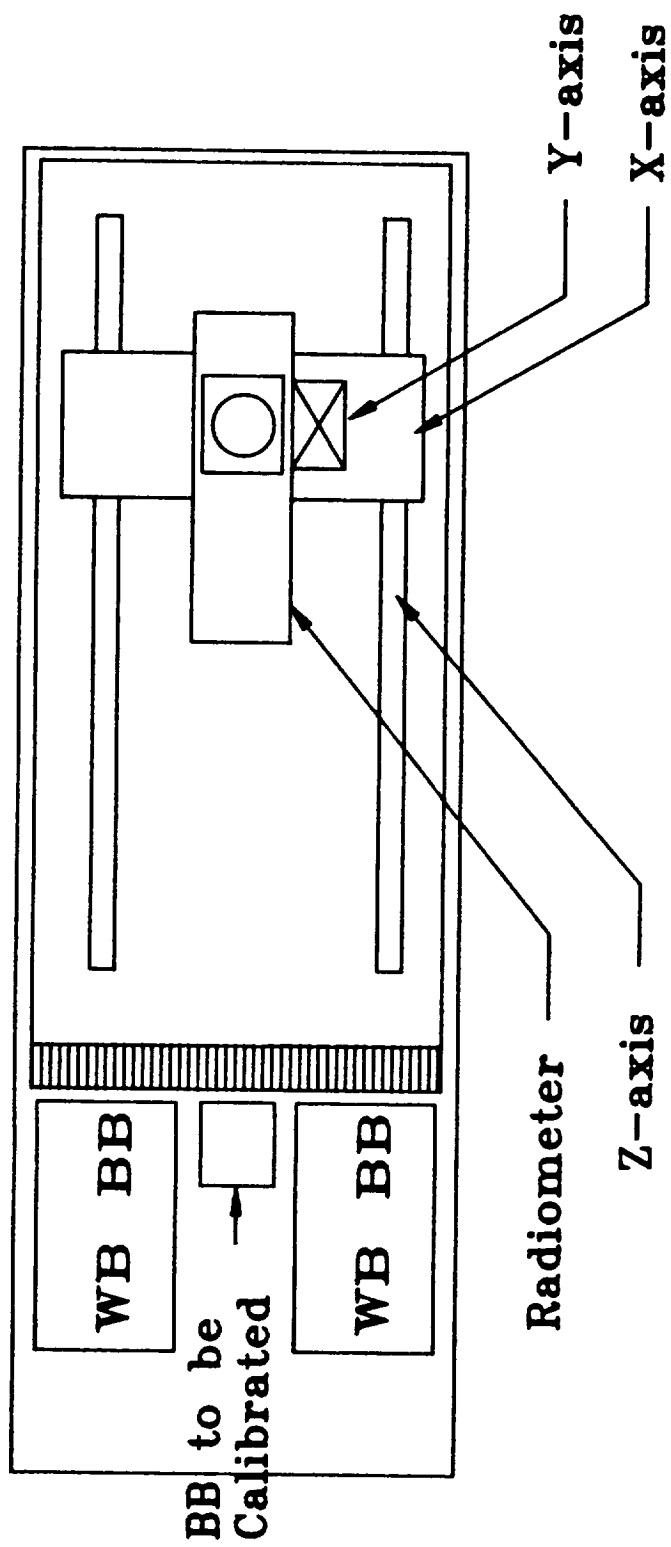


Figure 2. Simplified Schematic of the Ambient Temperature Blackbody Calibration Facility

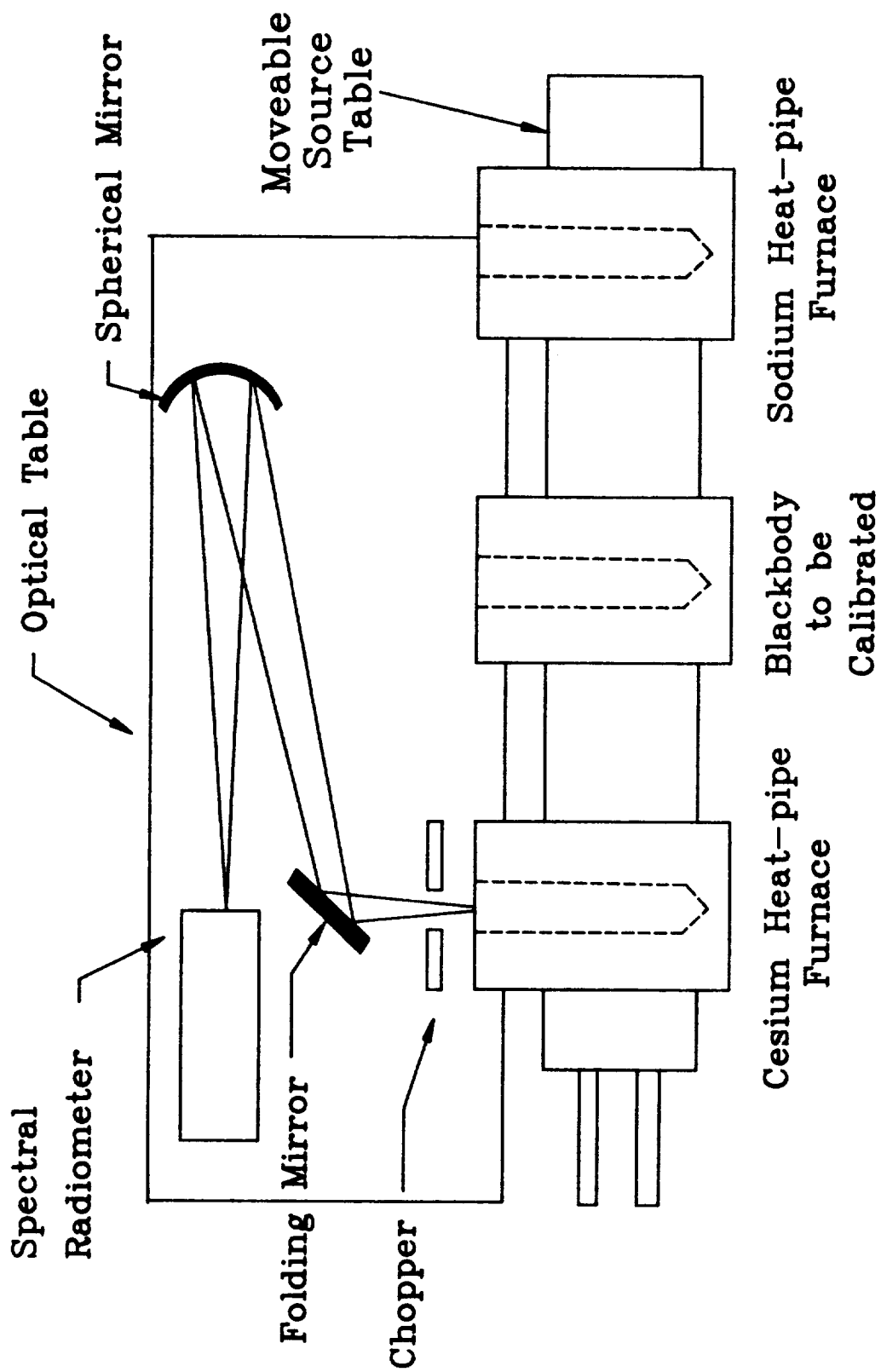


Figure 3. Simplified Schematic of the Medium Temperature Blackbody Calibration Facility

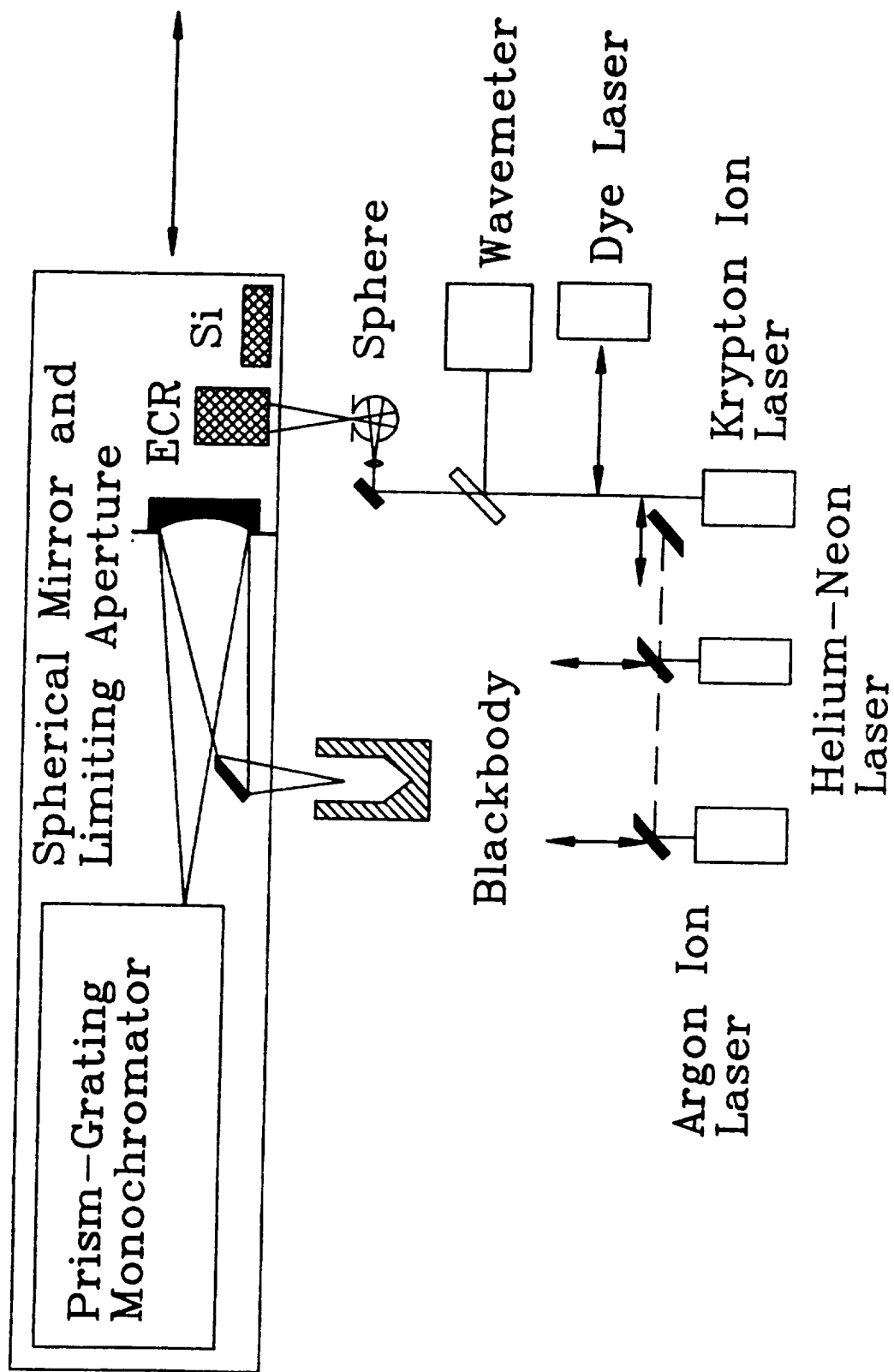


Figure 4. Radiometric Measurement of the Freezing Point of Gold